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SOME STRUCTURAL FEATURES IN THE BARRABOOL HILLS

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Introduction

The Barrabool Hills, near Geelong, consist of arkose, felspathic mudstone, grits and conglomerates. The age of these lacustrine sediments, long regarded as Jurassic, has lately (Cookson and Dettmann 1958) been referred to the Lower Cretaceous.

The N. and S. limits of the Barrabool Hills are defined by two pairs of step-faults running approximately E.-W. The N. pair, the Barrabool and Newtown Faults, reveal vertical displacements of more than 230 ft. to the N., approximately along the course of the Barwon R.; the S. pair at Waurn Ponds have throws of only 30 ft., and are expressed as monoclinal folds in the overlying Tertiary limestone.

These and other structures are discussed in the following order:

- the Barrabool Fault and associated 'Newtown' Fault,
- the Highton 'Warp',
- the Waurn Ponds 'Monoclines' and faults,
- the Moolap Graben,
- the S. cliffs of Corio Bay,
- the overlap at Gnarwarre and Modewarre,
- N. limit of the Lower Cretaceous sediments.

The Barrabool Fault

The W. end of this fault begins at Pollocksford, where the Lower Cretaceous beds on the S. bank of the Barwon R. have dips up to 55° N., whereas the general dip over most of the area is 8° NE. Some rocks here show evidence of slickensides. From Pollocksford the fault can be traced to George's Hill near Ceres Bridge (Fig. 2); the upthrow side shows rounded spurs at Lower Cretaceous rising to 600 ft., while the downthrow side is a basalt plain at 100 ft. altitude on the N. side of the river.

The only outcrop of Lower Cretaceous N. of the river is a small area in the river bend E. of Sugarloaf Hill. In this, the dip is 10° S., supporting the idea that the river marks the fault line.

At George's Hill, Ceres, the vertical displacement of the Tertiary (Janjukian) limestone provides evidence of the fault. Flanking the diabase (epidiorite) ridge of George's Hill at 400 ft., and forming a small plateau extending E. to Merawarp Road, this limestone is at a much higher level than the Batesfordian limestone N. of the river. Uncertainty still exists as to whether the Batesfordian is a facies variation of the Balcombian, or Janjukian. However, the upper beds at Fyansford and Batesford are Balcombian, and occur at levels up to 170 ft. Thus if Janjukian does underlie them, it must be at least 230 ft. below the George's Hill outcrop.

These facts also furnish some evidence of the age of the Barrabool Fault. Since no Balcombian is found on the S. upthrow side, while a considerable thickness of it occurs in the Fyansford-Batesford valley underlain by Batesfordian and probably Janjukian limestone, the uplift probably occurred at the close of the Janjukian sedimentation.

Newtown Fault

The E. half of the Barrabool Fault appears to be stepped S.-wards about 1 m., relative to the W. half, so that the two parts of the fault are 'en echelon' (cf. Fig. 1). It is provisionally called the Newtown Fault, as its most significant geological effect is seen on the two sides of Queen's Park Road, Newtown. On the N. side of this road is the typical Fyansford Hill sequence: from river level to 170 ft. is Balcombian clay, overlain by 3-in. layer of phosphatic nodules, 10-15 ft. of Lower Pliocene sands, capped by 15-20 ft. of Newer Basalt. On the S. side of the same road the rock is Lower Cretaceous sandstone and mudstone. No actual contact of Tertiary and Mesozoic can be observed here, but their juxtaposition can only be due to a fault.

At the river bend which may be called 'Conglomerate Bend' W. of Queen's Park, where there is an excellent cliff face exposing the Lower Cretaceous conglomerates, a small outcrop of steeply tilted Balcombian clay occurs on the river bank several chains to the N. of the bedded conglomerates. It is overlain in part by scree from the conglomerate beds, and probably does not rise more than 15 ft. above river level. The Newtown Fault must run between the two formations, but landslips and scree obscure any contact.

Between Conglomerate Bend and Gleeson's Hill, some recession of the fault scarp has occurred, due possibly to the temporary lake formed there when the

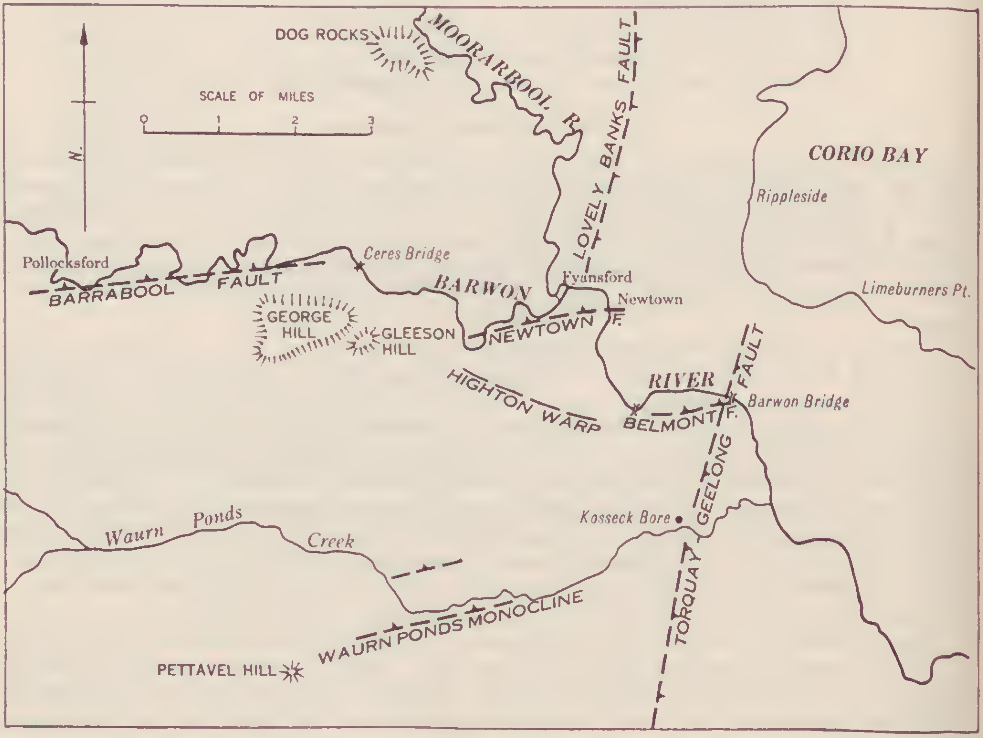

Fig. 1.—Fault Pattern in Barrabool Hills.

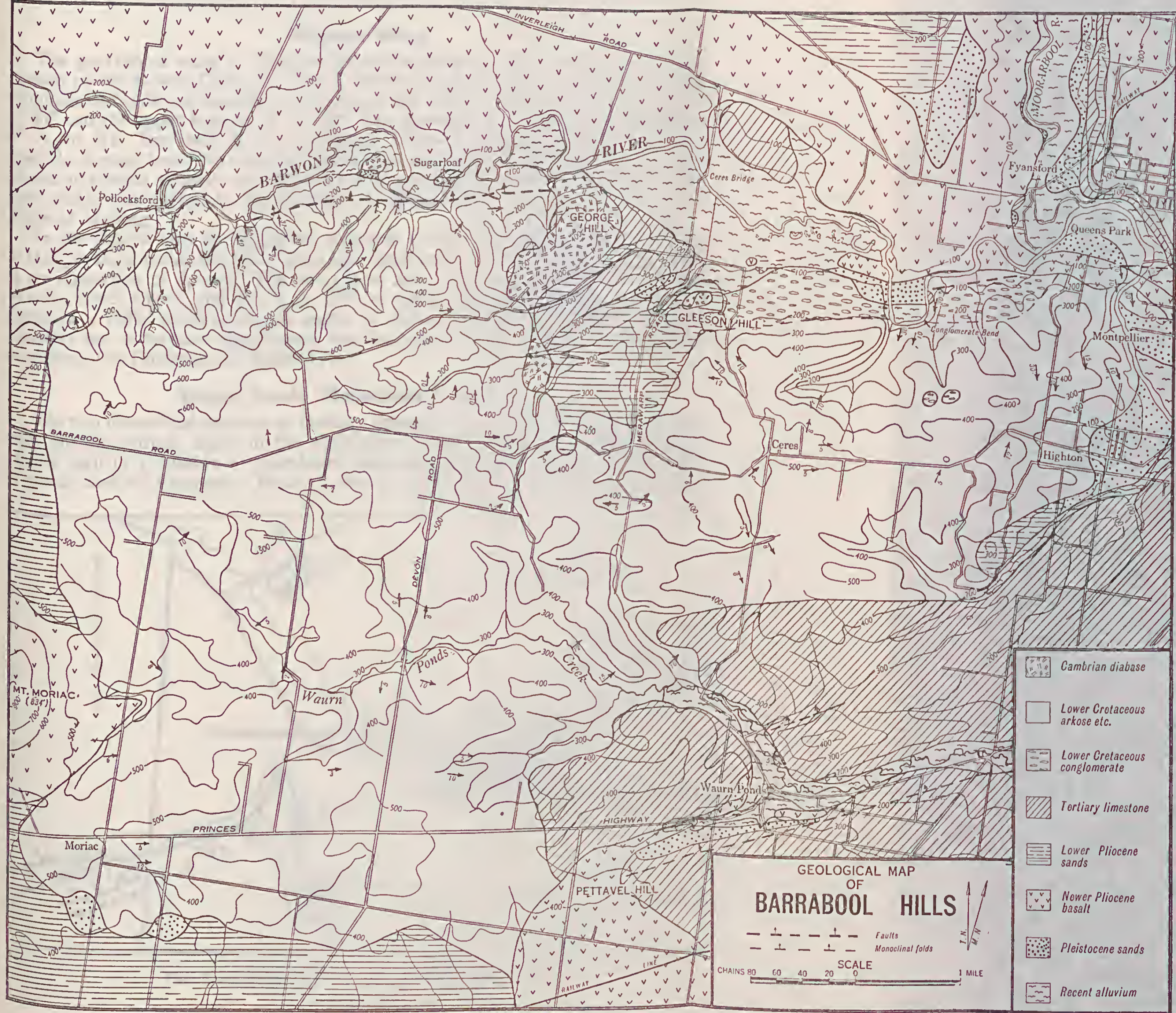

Fig. 2.—Geological Map of Barrabool Hills.

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waters of the Barwon were dammed by a lava barrier. When this was breached, an alluvial flat 2 m. long and 1 m. wide was left S. and E. of Ceres Bridge.

Highton Warp

The provisional name of 'Highton Warp' is given to this structure in the NE. portion of the Lower Cretaceous block. Between Queen's Park and Highton, the conglomerate beds and associated sandstones dip strongly to the S.; the lower beds at 30° and the upper beds at 15° or 10°. The general dip S. of Barrabool Road is 8° N. or NE. Barrabool Road in Highton Valley thus marks the trough of the inwards-dipping beds. No actually folded beds are exposed, so it cannot be determined at present whether the structure is a syncline or a fault. The term 'Basal Beds Fault' was applied to the structure (Coulson 1930), but there is no field evidence of faulting.

In the Balook area in Gippsland, Edwards (1942) described a dome structure in the 'Jurassic' rocks, but apart from two small areas in the Barrabool Hills, there is no suggestion of doming. The two places are: (i) where Devon Road crosses Waurn Ponds Creek, and (ii) ½ m. SW. of Ceres village. Here the directions of dip show a radial pattern, but the angles of dip are so slight that the features are probably not of tectonic significance, but due rather to the haphazard method of deposition (cf. Edwards and Baker 1943).

Waurn Ponds 'Monoclines' and Faults

The two monoclinal flexures in Tertiary limestone, possibly Oligocene, associated with dip-slip normal faults in the underlying Lower Cretaceous mudstones, are readily seen in a number of abandoned limestone quarries alongside the Prince's Highway and off Cochrane's Road. A line of State Electricity Commission posts,

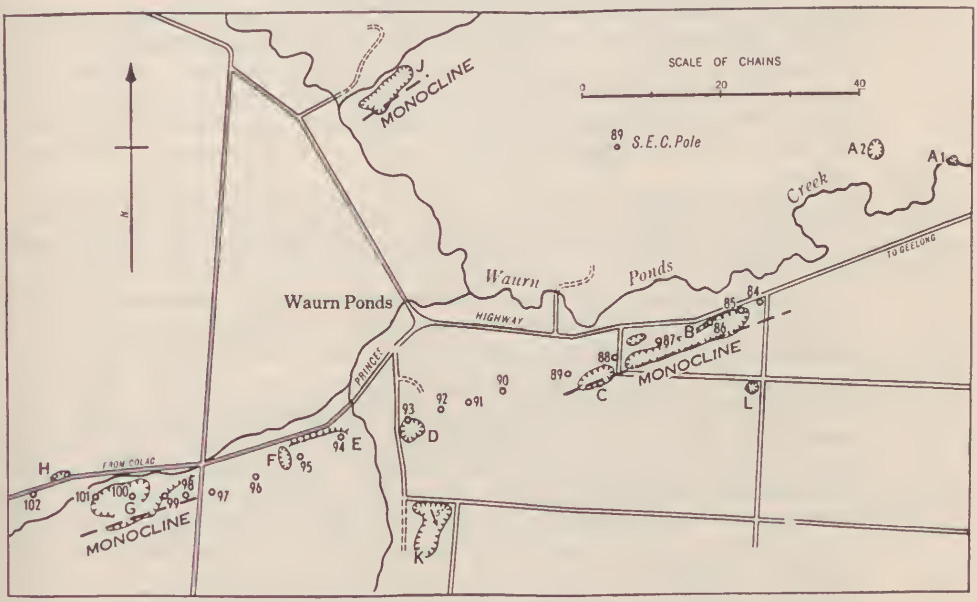

FIG. 3.—Locality Plan of Waurn Ponds Quarries.

numbered successively, facilitates reference to positions. Between the two formations there is usually a thin band of rolled brown pebbles of Older Basalt (Coulson 1937). These may have been derived from flows at Airey's Inlet, Maude or Bellarine Peninsula, or possibly a nearer vent now covered by Tertiary sediments.

The 'monoclines' are actually asymmetrical synclines, with very steep legs on the S. side, abutting against Lower Cretaceous mudstone, usually with a few inches of puggy material between the two. A few feet away from the Tertiary limestone, the Lower Cretaceous beds appear to be bedded horizontally, not conforming to the folding of the Tertiary.

As a result of the faulting, the junction of Lower Cretaceous and Tertiary appears at different levels along N.-S. traverses. It also has a downward trend to the E., descending from 320 ft. at Waurn Ponds West (S.E.C. Post 102) to 130 ft. near Waurn Ponds Bridge (S.E.C. Post 72), a drop of 190 ft. in 1½ m., or 1 in 40.

Fig. 3 shows the positions of the localities referred to by letters in the following detailed descriptions:

A1.—Tertiary polyzoal limestone dips 2° E., in bed of Waurn Ponds Creek, altitude 130 ft.

A2.—Tertiary limestone in marl pit, horizontal, altitude 170 ft.

B. — Quarries between S.E.C. posts 85 and 87. Altitude 150 ft. S. face shows Tertiary limestone downfolded to N. at a steep angle with vertical displacement of 30 ft.

C. — Quarry W. of 'Quarry Road' near S.E.C. post 88. The Tertiary limestone is folded in an asymmetric syncline, the vertical beds being in contact with soft Lower Cretaceous mudstone which shows some patches of slickensides. Altitude of junction on quarry floor is 180 ft.

D. — Sand pit near S.E.C. post 93. Altitude 250 ft. Upper Pliocene or Pleistocene grits consisting of abundant large quartz grains, occasional Ordovician spotted slates, quartzites, quartz pebbles and mica schists, with lenses of white clay. The whole formation is strongly cross-bedded and dips to the E. The upper beds are cemented by ferruginous matter, some of which contains replaced Tertiary fossils such as bryozoa and echinoid spines.

E. — Quarry and old kiln at S.E.C. post 94. Tertiary limestone bedded almost horizontally, rests on Lower Cretaceous sediments also horizontal. Junction at 275 ft.

F. — Gully erosion near S.E.C. post 95 reveals similar grits to those at Locality D. The deposit is continuous between them. The beds, strongly current-bedded, dip E. at angles up to 45°.

G. — Large quarry, altitude 300 ft., near S.E.C. posts 99 and 100. The almost vertical S. leg of Tertiary limestone abuts against Lower Cretaceous mudstone. The limestone has been sheared by a minor thrust fault causing a lateral displacement of 5 ft. or so. At the W. end of this quarry, structural relationships are complex. The folded Tertiary beds abut against Lower Cretaceous mudstone which is about 10 ft. wide, but instead of this being continuous into the S. bank, it is succeeded by a vertical band of concretionary ironstone about 1 ft. thick, and on the S. side of this are unbedded mottled clayey sands, similar to others in the Geelong district regarded as of Lower Pliocene age. Possibly the vertical bed of ironstone concretions occupies a small fault; the longer axes of the ellipsoidal concretions are in the vertical plane.

A flow of Newer Basalt, filling a former valley, overlies these formations at the W. end of the quarry. Its source was Pettavel Hill, a minor vent 400 ft. high, whereas the Mount Duneed flows further S. are at 250 ft.

H. — Road embankment on N. side of Colac Road, near S.E.C. post 102. Tertiary limestone rests horizontally on Lower Cretaceous mudstone at 320 ft., separated by a thin band of Older Basalt pebbles.

J. — Waurn Ponds North. Quarry in Tertiary limestone at 200 ft. Monoclinal fold trending 060° Mag., lowers limestone 30 ft. to the N., with Lower Cretaceous on floor and S. wall.

K. — Large quarry in Tertiary limestone on summit of scarp. Quarry face of 30-40 ft., shows a dip of 5° SE. Lower Cretaceous mudstone at 350 ft., nearly horizontal.

L. — Tertiary limestone at 250 ft., horizontal.

Summarizing the above evidence, it is clear that two small parallel E.-W. faults in the Lower Cretaceous at Waurn Ponds have caused downfolding of 30 ft. in the overlying Tertiary limestone. There is a strong resemblance in attitude between the Tertiary limestone at Waurn Ponds and that at Curlewis (Coulson 1933), though in the latter case the underlying rock is Older Volcanic.

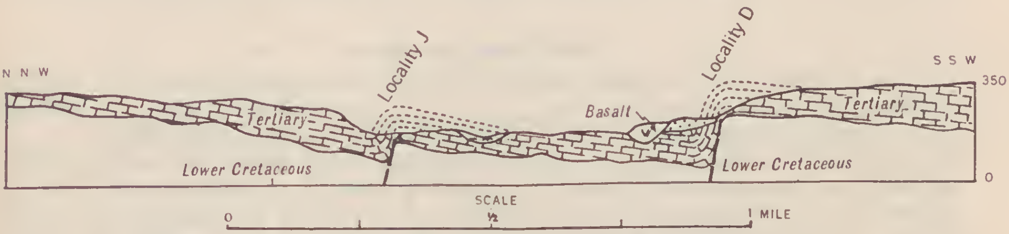

Fig. 4.—Section through Waurn Ponds area from N. to S.

The Moolap Graben

The Tertiary (Janjukian) limestone forms a wedge, thickest in the SE. at Torquay, and thinning out at Waurn Ponds North and Highton. No Balcombian beds overlie the Janjukian at the latter places. At Highton, near St. Catherine's Orphanage, there are ferruginous sands similar to the Lower Pliocene (Kalimnan) beds at Moorabool Viaduct, W. bank.

This wedge of limestone dips E. at a gradient of perhaps 1 in 40, say 2°. If this dip persisted, the base of the Janjukian should be about 250 ft. below sea level at Grovedale, 2½ m. E. of Waurn Ponds. At Grovedale a very interesting private bore for water was put down in July 1957 on Kosseck's vegetable farm alongside Torquay Road (Mil. Ref. Corio Special 412898). From a surface altitude of 50 ft. the bore penetrated 310 ft. Mr. A. Kosseck preserved samples from the bore, and these have been examined by Mr. E. D. Gill, Curator of Fossils, National Museum of Victoria, Melbourne, who considers the material at 310 ft. to be probably Balcombian. The log of the bore reads:

	Thickness	*Depth*
Soil	2′6″	2′6″
Sand and sandy clay, red	20′6″	23′
Wet sand	4′	27′

Sandy clay	17′	44′
Grey and blue clay	15′6″	59′6″
Grey sandy clay with fine shells	6″	60′
Hard limestone and marine clay	40′	100′
Sandy limestone	32′	132′
Grey-green marine marl	4′	136′
Hard and soft limestone	66′	202′
Quartz sand	23′	225′
Brown sandy clay	35′	260′
Shelly mudstone	18′	278′
Green mudstone	9″	278′9″
Hard sandstone	4′3″	283′
Coarse sand with shells	9′	292′
Very coarse sand, with shells	18′	310′

It would appear that the base of the fossiliferous beds was not reached, although a lithological change occurred at 283 ft. The Janjukian beds, if present, must be below 310 ft. in the bore, or 260 ft. below sea level. Thus their base would be considerably lower than the calculated depth mentioned previously, i.e. with the base at 250 ft. below sea level. This drop in level may be due to a fault or a fold, running N.-S. The former possibility was postulated (Coulson 1939) as the Torquay-East Geelong fault, on the W. side of the Moolap Graben or sunkland.

That a considerable thickness of Tertiary beds does exist nearby was shown by the Mines Department bore at Mt. Duneed State School, which penetrated 810 ft. of Tertiary, mostly shelly clay and marl, before bottoming on Lower Cretaceous beds.

The Corio Bay Area

The W. cliffs of Corio Bay at Rippleside consist of approximately 40 ft. of Balcombian clay and limestone, overlain by 10 ft. of Lower Pliocene sands. E. of these cliffs, near the Cunningham Pier, the Lower Pliocene forms the low cliffs, as shown when excavations were made for the new Harbour Trust offices. At Eastern Beach, the cliffs are Pleistocene limestone, underlain in places by Newer Basalt. There is no evidence as to the cause of this tilt to the E. Possibly it is a minor fault parallel to the Lovely Banks and Anakie-Rowsley faults further W., forming step faults. More probably it is due to the N. end of the East Geelong-Torquay fault. Fig. 1 shows these faults.

No outcrops of Tertiary limestone occur between the Corio Bay frontage and the Barwon River. The City of Geelong is built on basalt or basaltic clay, resting on Lower Pliocene red and grey sandy clays. However, on the S. bank of the Barwon there is a bold spur and curved scarp of Tertiary (Janjukian) limestone, over 50 ft. high, at North Belmont. This suggests the possibility of a fault along the straight course of the Barwon from Prince's Bridge to Barwon Bridge. It may provisionally be called the Belmont Fault.

Progressive Overlap in the Gnarwarre-Modewarre Area

Immediately flanking the W. and S. margins of the Lower Cretaceous block are deposits of ferruginous grits and ironstone similar to the Lower Pliocene (Kalimnan) ironstone of the Moorabool Viaduct W. bank. Further away from the Lower Cretaceous block, limestone of Tertiary age is intercalated between the formations, and is exposed in river sections at Murgheboluc and Birregurra. This overlapping relationship indicates that in these parts there were no fault movements. Probably a low saddle occurs in the Lower Cretaceous between the Barrabools and the Otways, and is occupied by various Tertiary beds, including brown coals.